

Potato production and consumption in developing countries

FAO
PLANT
PRODUCTION
AND PROTECTION
PAPER

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FOREWORD

This publication describes the important changes that have taken place in world production and consumption of potatoes during the last 20 to 30 years and discusses the technical and scientific progress that has been made in the fields of potato breeding, production and protection.

Although the potato was widely cultivated throughout the regions of Inca civilisation in the Andes, the species remained at a low level of productivity until it became a commercial crop in Europe in the 19th century. Thereafter, great interest in production resulted in improved selection and cultural techniques in the cool temperate zones and led to serious scientific work from the early 20th century. This had little effect in the tropical homeland of the potato, and it has only been in the second half of the century that serious efforts have been made to improve the crop in developing countries. There is now clear evidence that suitable varieties can give high yields over a considerable range of tropical and sub-tropical climates and whereas production is rather static in developed countries, it is increasing rapidly in many developing ones.

This paper has been prepared by Roots and Tuber Crops Officer, Winston B. Charles in co-operation with L. Boyce Thrower, Consultant. It draws attention to the high potential productivity of the potato crop in terms of human nutrients per hectare and the development possibilities involved. Technical constraints in the new production areas are discussed, especially those concerning plant material, propagation and protection, and an outline is presented of the pioneer work in research and development carried out since the 1970's under the leadership of the International Potato Center in Lima, Peru. The significance of these efforts is now widely acknowledged and it is hoped that the following review of the subject will be of interest to agronomists, economists and administrators in FAO member countries currently concerned with the development of food crop production.

Director
Plant Production and Protection Division

This One



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I. INTRODUCTION

Population Growth

All questions relating to food production in developing countries should be based on considerations of population growth. According to U.N. estimates, world population in 1960 was approximately 3 billion and is now over 5 billion. By the year 2025, it is expected to exceed 8 billion. As population in the developed countries is reaching an equilibrium, most of the expected increase will occur in developing countries.

Table 1 gives estimated population figures ⁽⁶⁾ for 1975 and 1988 in the "Developing Market Economies" (i.e., the poorer countries of the non-communist world). It will be seen that population increases are in the region of 3% per annum. For present purposes, it is perhaps sufficient to emphasise the orders of magnitude of these estimates, with examples from Africa and the Far East.

Over this 13-year period, African populations have grown by around 48% with about 161.5 million extra people. Two of the most rapidly growing populations have been in Nigeria with a 56% increase - and nearly 38 million extra people - and in Rwanda with a 54% increase - and 2.4 million extra people.

In the Far East, the populations over the 13-year period have grown by about 34%, with about 374 million extra people. Two of the most rapidly growing populations have been in Bangladesh, with a 43% increase and about 33 million extra people and Indonesia, with a 29% increase and about 39 million extra people. Increases in the Near East and Latin America are of the order of 44% and 30% respectively.

Table 1 Population in Developing Market Economies (millions)

Total	1975	1988
Total	1,955.9	2,682.4 (+ 726.5)
Africa	335.0	496.5 (+ 161.5)
Latin America	332.8	430.2 (+ 97.4)
Near East	185.2	267.1 (+ 82)
Far East	1,108.3	1,482.3 (+ 374)
Others	4.5	6.2 (+ 1.7)

Source: FAO Production Yearbook, 1988.

These national population increases are sufficiently alarming, but future plans for food production must take special note of the extra rapid growth of urban populations.

The following quotations from the United Nations World Economic Survey 1989, give examples of the growth rate of five of the largest urban agglomerations in Latin America, Asia and Africa, showing their world rank in urban populations.

Table 2: Estimated Population Growth 1970-2000 in Five Major Urban Agglomerations

World Rank in Population, 1985	Urban Agglomeration	Country	Population (Millions)		
			1970	1985	2000*
2	Mexico City	Mexico	8.74	16.65	24.44
4	São Paulo	Brazil	8.06	15.54	23.66
10	Seoul	Rep. of Korea	5.31	10.07	12.97
13	Greater Bombay	India	5.81	9.47	15.43
18	Cairo/Giza	Egypt	5.33	7.92	11.77

* = Estimated

Such population statistics as are available for smaller towns in developing countries nearly all show large increases since 1970, but not as great as those in the major urban agglomerations. The general conclusions are that in the Third World there is a rapid increase in population and emigration from rural areas in nearly all countries, that there is, therefore, an extremely rapid urbanisation, and that the most rapid increases in population are in the major urban agglomerations.

Urban Food Supplies

The particular menace of the urban population explosion is that enormous quantities of food must be transported to the cities, frequently over long distances. Over the last 10-15 years, an increasing proportion of the food for the large cities, often situated at or near sea ports of the developing world, has been supplied by imported shipments of cereals. Many Asian countries have been able to pay for such

imports, but many African and Latin American countries have had to obtain credit and/or accept food aid. If the credit and food aid from wealthy grain-producing countries is severely diminished over the next decade, as is possible, the result will be large-scale urban famines.

The obvious solution to this terrible danger would be to increase food production in the developing countries, but plans to do so have met many obstacles. In addition to the many agricultural problems, subsidised wheat and rice imports have had a depressing effect on prices and poor urban markets have not then offered price incentives to cover transport over long and poorly maintained roads and also reward the farmer and merchant.

Food Self-Sufficiency

The developing countries that are the worst hit by food shortages are mostly situated in the tropical and sub-tropical regions and the substitution of imports with locally grown cereals raises ecological problems. Where rain or irrigation water is plentiful, rice imports could be partly replaced by "home-grown" rice, but in many cases and according to conditions of climate and transport it may be necessary to substitute both rice and wheat imports with locally grown maize, millets, roots and tubers.

In the tropical regions, cassava and sweet potatoes will, as a rule, be the easiest of the root crops to develop, but while the quantities of Solanum potatoes marketed are at present on a relatively small scale, there is a remarkably widespread interest in the crop. The technical problems which confront potato production in developing countries will be discussed later, but it should be noted that among some remarkable changes in consumer demand in developing urban communities, there is a new-found enthusiasm for potatoes wherever families can afford the current prices. Certainly potatoes will not, alone, solve the impending tropical and sub-tropical food crises, but millions in the Middle East and North Africa are already potato eaters, and even among the rice-loving people of Java the pioneer potato production in the highlands round Bandung finds a ready market!

II. PRODUCTION POTENTIALS IN DEVELOPING COUNTRIES

Environmental Requirements

Most commercial cultivars of potato tuberize best with mean temperatures just above 15.5°C (60°F) but will yield with temperatures between 15.5°C and 24°C (75°F). Little or no tuberisation occurs at about 27°C (80°F). Cool night temperatures are more important for production than cool day temperatures, since the yield of tubers depends on the amount of carbohydrates available in the plant for translocation, when the needs for respiration and vegetative growth are reduced. In the short day-length conditions of the tropics, it is found that maximum yields can usually be obtained where cool nights operate at elevations between about 270 m (900 ft) and 1350 m (4500 ft). It is also found that high light intensity during the day favours production through its effect on photosynthesis. An ideal potato climate would thus combine a high proportion of clear skies with a well-distributed rainfall. Such conditions are not uncommon in tropical highland regions.

Suitable growing conditions can also be found in sub-tropical lowlands, but in tropical lowlands, production has so far only proved possible where cool winds are responsible for a cool growing season of 3-5 months. In lowland areas, care to ensure good drainage is also of great importance.

Potatoes are tolerant of a rather wide variety of soils. If heavy clays are avoided, good growth can be obtained in anything from light sandy soils to fairly heavy loams. Deep soils with a good water retention give best growth and the lighter soils are said to produce a better shape and colour in the tubers. Soil temperatures should not usually exceed 24°C (75°F).

Production Development

Potatoes, in fact, may become a valuable element in tropical and sub-tropical agricultural development, wherever there is a 3-5 month cool season reasonably near a large market. In this connection, it may be argued that although potatoes are a bulky crop containing up to 80% of water, compared with the 15% of cereals, production within a few hours' drive has the advantage of a highly intensive and remunerative crop which yields 2.3 tons of dry matter and 7.1 million kcal plus 196 kg protein per ha. These figures compare well with cereal yields and, due to the shorter growth cycle of the potato crop, are competitive with those of yams, sweet potatoes and cassava⁽¹⁰⁾ when productivity is reckoned in Kg/ha/day.

The potential changes in potato production may be looked at in the historical perspective. The potato crop, which apparently originated in the Peru-Bolivian region at least 8000 years ago, spread through the Andean highlands rapidly during ancient civilisations⁽⁹⁾. At the time of the Spanish conquests in the early 16th century, it was found to be widely cultivated in South America. The potato arrived in Europe, probably first in Spain and then in England, in the late 16th century, whence it spread throughout the world during the 17th and 18th centuries. According to Hawkes⁽⁹⁾, field scale production started in Ireland from the early 17th century but elsewhere commercial development in the temperate zone was mostly delayed until the 18th and 19th centuries. The great increase in production and productivity that occurred in that period in developed countries was unknown in the tropics. Indeed, until the 20th century it was only in the highlands of South America that potato production of any sort could be found in the tropical zone. Techniques in the Andes, however, remained traditional and productivity was low. It will probably be in the 21st century that potatoes will be fully developed as a tropical food crop.

It is not yet known what areas will be first developed with new varieties or which urban areas will provide large markets, but it is safe to say that the next ten years will show a great interest in supplies of improved, tropical varieties and an increasing demand for information on related questions of potato propagation, production, protection and storage, under conditions strange to the temperate world.

Production Regions in Developing Countries⁽⁶⁾

Temperate Zones

Both lowland and highland regions with a temperate climate offer good potato growing conditions during the summer months in, for example, southern Argentina, Chile, China, the USSR, the Korean peninsula and Afghanistan.

Although the subject of this paper concerns potatoes in developing countries and concentrates attention on tropical and sub-tropical regions, reference must also be made to the great provinces of the USSR and China, some of which are, in agricultural matters, developing economies. These two countries together produce a large proportion of the world's potatoes. According to preliminary FAO estimates, the 1989 crop in China amounted to 30 million tons and in the USSR, 72 million tons.

According to FAO estimates, the Chinese crop has been increasing over the last ten years and the USSR crop decreasing. These crops are produced under a great range of conditions as regards temperature and rainfall. Productivity in both China and USSR is reported as averaging between 10 and 12 tons/ha, which seems to indicate room for improvement.

Lowland regions with sub-tropical and Mediterranean climates offer good conditions for potato production in their winter and spring seasons. Such conditions occur in large areas of lower Egypt, Tunisia, Morocco and northern Algeria and in vast stretches of the Indo-Gangetic plain from Pakistan through India into Bangladesh. There are also important areas with a Mediterranean-type climate in Cyprus, Iran and Iraq. Most of the land of Bangladesh is also just outside the tropics and potatoes are grown successfully in the northern region.

Highland Tropical Zones (between Tropics of Cancer and Capricorn)

There are many regions between 270 m and 1350 m elevation in the tropical parts of all continents which offer suitable seasons for potato

growing over a large part of the year. In Africa, such regions may be found in the highlands of Kenya, Uganda, Burundi, Rwanda, Zaire, Ethiopia, Madagascar and Malawi. In South America, potatoes are grown throughout much of the Andean regions of Colombia, Peru, Bolivia and Ecuador and in the central highlands of southern Mexico. In Asia, potatoes are grown in the highlands of Java, Malaysia and the Philippines.

Lowland Tropical Zones

These offer smaller opportunities for potato growing, but maritime influences encourage production, for example, in some Caribbean countries and the coastal areas of Peru. [Cuba, classified as a "centrally planned economy", should be included in this production region.] Choice of variety and time of planting are critical in these cases.

Note: Tropical regions and climates are here defined as all those between latitudes 24°N and S, irrespective of altitude, temperature and rainfall. Sub-tropical regions and climates are those areas adjacent to the tropics (North of the Tropic of Cancer and South of the Tropic of Capricorn) with a clearly defined winter season but no prolonged frosts at sea level below -5°C.

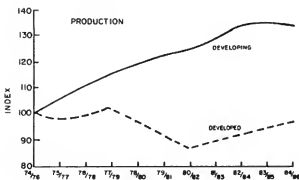
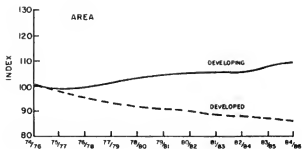


Fig. 1 Development of the area cropped with potatoes and total production in all developing and developed countries. Three-year moving averages derived from FAO Production Yearbooks.

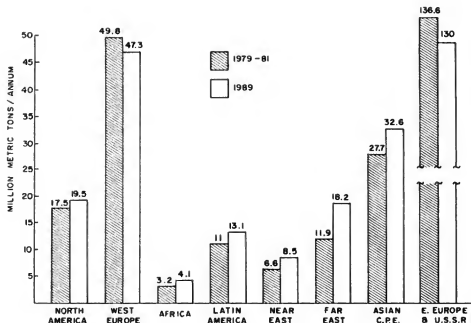


FIG. 2. ANNUAL POTATO PRODUCTION BY REGION 1979-81 AND 1989 (MILLIONS METRIC TONS)

Fig. 2 Note: North America = Canada and U.S.A. (Developed Market Economies)
 Latin America = Mexico, Central and South America (Developing Market Economies)

Footnote: Statistics for Africa, Latin America, Near East and Far East from FAO Statistics for Developing Market Economies in each of these regions. Statistics for Asian CPE/E. Europe and USSR from FAO Statistics for Centrally Planned Economies.

Recent Changes in Levels of Production and Productivity in Developed and Developing Countries

Fig. 1 illustrates the changes in area devoted to potatoes and the total production by weight in "developed" and "developing" countries over the 12-year period 1974-1986⁽¹⁴⁾.

It will be seen that in developed countries (primarily North America and northern Europe, plus eastern Europe and the USSR), the area decreased by 15%. Total production also decreased, but only by about 2%. This reflects the fact that in the North American continent the area remained stable, productivity improved and gave a production increase of 11%, while in western and eastern Europe and the USSR, although the area showed a marked decrease, increases in productivity limited the loss in production to 5%.

In developing countries (all developing market economies, plus Asian centrally planned economies - mainly China), there was a total increase in area of about 10% and this, combined with a large increase in productivity, resulted in a remarkable increase in production of 35%. This increase, both in terms of percentage and total production, was predominantly the result of progress in Asia.

To be seen in perspective, these increases and decreases should be compared with the magnitudes of total production illustrated in Fig. 2.

For the year 1989, these show production in North America and Western Europe at nearly 67 million tons, Asian production at nearly 60 million tons (including China with over 30 million), and East Europe plus USSR at about 130 million tons. By contrast, the total productions in the same year for Africa (7 million), and Latin America (13.1 million) seem relatively minor, although in each of the latter cases the

Note: Figs. 1, 3 and 4 are from Van der Zaag⁽¹⁴⁾ and are based on statistics from FAO Production Yearbooks. Fig. 2 is based on FAO statistics (Annex A).

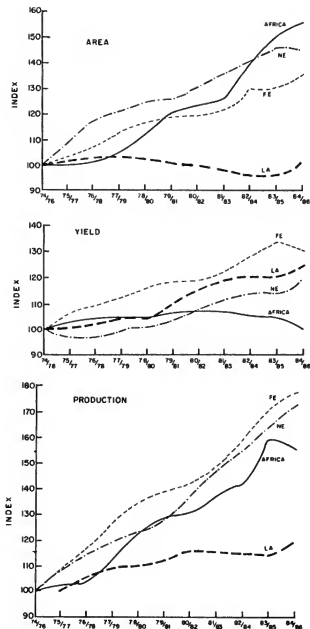


Fig. 3 Developments in area cropped, yield and total production in developing countries with market economies in: Africa, Latin America (LA), Near East (NE) and Far East (FE). Three-year moving averages derived from FAO Production Yearbooks.

production for 1989 shows a marked percentage increase over average production for 1979-81.

The figures for Western Europe show a noteworthy production decrease over the period of nearly 2.5 million tons, equivalent to 5%. The production in East Europe plus USSR shows a similar percentage decrease over the period.

Comparative Changes in Developing Market Economies

The three graphs of Fig. 3 illustrate the different rates of development in the area, yield and total production of potatoes in the African, Near Eastern, Far Eastern and Latin American regions over the ten-year period 1974/76 to 1984/86⁽¹⁴⁾.

In production areas, it will be noted that Africa - with the smallest total production area - shows the highest rate of increase - over 50%. The Near Eastern and Far Eastern regions show increases of about 45% and 35% respectively, but the Latin American region shows almost no increase in area.

In yield per ha. however, the African region shows little improvement over the period, but rather steady increases were obtained in the other three regions: approximately 30% in the Far Eastern, 20% in the Latin American and nearly 20% in the Near Eastern region.

These changes in area and productivity worked out in increases in total production of approximately 76% Far Eastern, 70% Near Eastern, over 50% African and 15% Latin American regions.

*Footnote: As China is not classed as a market economy, it is not included in these figures for the Far East region.

The range of average productivity per ha. in different developing countries during recent years is indicated by the following statistics (see Annex A):

Productivity in developing countries in sub-Saharan Africa was low - the lowest being Rwanda with 6.7 MT/ha in 1979/81 and 4.6 MT/ha in 1989. Productivity in North Africa was much higher - especially in Egypt with 17.4 MT/ha in 1979/81 and 21.9 MT/ha in 1989.

Productivity in developing countries in Asia was just as varied as in Africa, with, for example, 5.5 MT/ha in Nepal in 1979/81, compared with 16 MT/ha in India and the Republic of Korea in 1989. Similarly, the figures for developing countries in Latin America varied from Bolivia with 4.7 MT/ha in 1979/81 to Argentina with 24.8 MT/ha in 1989.

To put these figures for developing market economies into perspective, they may be compared with productivity in the leading potato growing countries. Over the same period, yields in the USA have ranged from 30-33.7 MT/ha. They have been regularly between 30 and 40 MT/ha in Belgium, the Netherlands, Switzerland and the U.K; sometimes exceeding 44 MT in Belgium and the Netherlands. Japan achieved 26.5-31 MT/ha during the same years⁽⁶⁾.

From the point of view of human needs, of course, the most important statistics are those of consumption per head. Fig. 4 shows that among developing market economies, in 1985, consumption per head in the Near East was about 27 kg per annum, compared with about 22 kg in Latin America, under 10 kg in developing countries of the Far East and about 6 kg in many African countries. These levels are all modest in comparison with the nearly 80 kg per annum consumed in Western Europe⁽¹⁰⁾.

In centrally-planned economies, there is also a great contrast between the developed economy of the U.S.S.R. and Eastern Europe - with a consumption of over 100 kg per annum - and the developing economy of China with 26 kg per annum⁽¹⁰⁾.

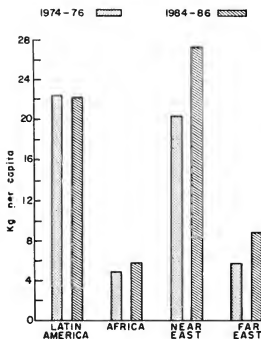


Fig. 4 Estimated consumption per head in developing countries with market economies in Latin America, Africa, Near East and Far East in the periods 1974-76 and 1984-86.

III. PRESENT CONSTRAINTS TO INCREASING PRODUCTIVITY

Potential Productivity

It is only in recent years and more especially since the establishment of the International Potato Center (CIP) near Lima, Peru in 1971, that much interest has been taken in the technical problems of potato growing in developing countries. This contrasts with the extraordinary 20th century progress in productivity in Europe - from 8-10 tons/ha in 1900 to 30-40 tons/ha at present!

It is not surprising that productivity in developing countries has often remained at that 8-10 ton/ha level, and in sub-Saharan Africa often at only 4-7 tons/ha, when it is realised that many tropical countries are still using varieties developed specifically for temperate conditions and that, until recently, little information on production and protection techniques adapted to their local conditions has been available. On top of these disadvantages come the economic constraints due to potatoes being a "high investment" crop. Many farmers in these countries do not have the means to buy the best planting material or the necessary fertilizers, pesticides, etc., to get good yields.

Research at CIP indicates that there are no a priori reasons why high yields should not be obtained in tropical and sub-tropical regions - indeed, productivities of 36 tons/ha have been reached under experimental conditions.

An example may be quoted here of productivity that can be obtained even at low altitudes in Africa, in some climates, under correct cultural treatment: In field trials over three years 1974-77 conducted by an FAO/UNDP assisted project near Dakar, Senegal, yields were obtained of the order of 34 tons/ha in the first year and 25-26 tons/ha in the second and third years, of the varieties 'Baraka', 'Cardinal', 'Spunta', 'Mirka' and 'Desirée'. Plantings were made monthly, November to February. The highest yields of 36 tons/ha were obtained from the January plantings of 'Spunta' and 'Desirée'. The trials were carried out in a favourable micro-climate in the coastal area of Senegal. The first plantings were started with the arrival of the cool maritime winds in November.

The general conclusion from reports and observations to date would seem to be that the essential constraints on yields in the Third World are basically the same as those in the rest of the world, but that the factors connected with differences of climate and environment have not yet been met with suitable modifications of plant material and cultural methods. As the potato is a tropical crop in origin, it should be possible to obtain results in many tropical and sub-tropical areas that are comparable with those in Europe and North America.

Some discussion of the major constraints follows.

Environmental Constraints

The difficulties created by excessively high temperatures are largely avoided in the sub-tropics by a choice of season - the crop in North Africa being grown during the winter and spring months.

In tropical countries, seasonal choice is important in the lowlands but the most satisfactory solution is to grow the crop in the highlands where a succession of crops can usually be grown for 8-9 months, avoiding only the seasons of heaviest rainfall. In some cases year-round production is possible.

Problems of day-length, however, can only be dealt with by selection and breeding, and here the recent work on breeding from Andean cultivars is the most satisfactory approach, although it has not yet had much commercial impact.

Propagation Constraints

The first problem facing any potato grower in developing countries is that of obtaining supplies of clean, healthy planting material of suitable varieties at an acceptable price. In many countries there are no provisions for local propagation and the import of seed potatoes is expensive and poorly organised.

Certainly the most satisfactory solution to this problem would be the use of true ("botanical") seed. It is estimated that approximately

a tea-cupful of true seed would provide enough seedlings to plant a hectare - instead of one or two tons of seed tubers! The care and expertise involved in propagating disease-free tubers means that they are always expensive and the additional high cost of transport from seed-tuber growing areas to most potato production areas in developing countries means that the cost of plant material is the biggest item of cash expenditure for the farmer. In the Third World, potato growers are usually small farmers and they often find themselves unable to afford good seed-tubers - and are thus condemned to low productivity. The effect of the availability of true seed of disease-resistant, high-yielding, tropical varieties on both costs and quality in developing countries would be enormous.

Unfortunately, breeders have not yet been able to create varieties of potatoes which can produce true seed of reliable stabilized character, and as yet there are no examples of the commercial use of true seed. A common estimate is that it may take as long as 15-20 years for breeders to overcome the genetic difficulties involved.

Another line of development is that of in vitro meristem cultures and rapid multiplication techniques, as discussed in Section IV. Besides offering a means of cleaning plant material of virus infections and providing a rapid nucleus of basic seed tubers, these modern systems may provide a means of multiplying new hybrid seedlings by vegetative methods.

Crop Protection Restraints

The crop protection problems for potatoes in the Third World might be described as the same as those in the developed countries - only worse. In hot, dry climates, insect attack is usually extra bad and in hot, wet climates and seasons, fungal and bacterial attack is extra virulent. It also seems that in all climates without a severe winter season, the nematode problem is particularly intractable. Virus infections, moreover, are common in all developing countries because of the difficulties in obtaining virus-free seed tubers. Among the worst pests and diseases occurring on potatoes in Africa⁽⁷⁾ are the following:

Fungi

Stem Rot -	<u>Rhizoctonia battaticola</u>
Powdery Mildew -	<u>Leveillula taurica</u>
Early Blight -	<u>Alternaria solani</u>
Late Blight -	<u>Phytophthora infestans</u>
Wilt -	<u>Fusarium lycopersicum</u>

Bacteria

Bacterial Wilt -	<u>Psuedomonas solanacearum</u>
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Virus

Mosaic Virus -	Potato Virus X and Y
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Nematodes

Root-Knot Nematode -	<u>Meloidogyne spp.</u>
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Insects

Potato Tuber Moth -	<u>Phthorimaea operculella</u>
Cutworm -	<u>Agrotis ypsilon</u>
African Mole Cricket -	<u>Gryllotalpa africana</u>
Peach Aphid (virus vector) -	<u>Myzus persicae</u>
Leaf Worm -	<u>Spodoptera littoralis</u>

Checklists for other continents are not available at present. It is clear from reports that 'Late Blight', 'Bacterial Wilt' and viruses are major problems in nearly all regions. 'Verticillium Wilt' is reported in Zaire and the 'Potato Tuber Moth' and the 'Cyst nematode' (Globodera spp.) are very prevalent in the Philippines.

It may also be noted that the potato tuber moth may now have reached every developing country where potatoes are grown, whether highland or lowland⁽¹⁰⁾.

The restraints on control of the above and other common pests and diseases are not, of course, that methods of control are unknown to science but that in the Third World both information and materials are in short supply. In order to protect his crops, the farmer needs a reliable service to identify the pests and pathogens, advice on control

methods and supplies of pesticides, and above all reliable supplies of pest and disease-free planting material.

Economic and Social Constraints

During the recent periods of warfare between some developing countries and social upheaval in many others, agricultural development has suffered. It is to be hoped that a period is coming when the pressing economic and demographic problems will be faced and it is obvious that food production must be among the first priorities.

As mentioned in our introductory remarks, the relations with countries that produce wheat and rice in excess of their national requirements may not guarantee indefinite extension of credit or expansion of food aid, so that a move towards self-sufficiency will be obligatory in all countries that can be truly classified as developing.

Political experience in the 20th century does not encourage the ideas of forcefully expelling urban populations to the countryside, or obstructing the movement of rural populations to the cities, and this means that food, transport, housing and some degree of social security will have to be provided in the towns, and some degree of industrialisation will have to follow.

The question of increasing national food production in many developing countries meets a complex problem. On the one hand, potential urban demand is inhibited because locally or nationally produced food cannot be offered at prices which compete with cheap grain imports. On the other hand, farm productivity remains low because farmers lack the required capital, inputs and information.

Government policy should ensure that farmers are offered an economic price for efficient production and that necessary inputs, transport, information and services are made available. This will mean that imported food is not offered at subsidised prices and, of course, this often presents political difficulties.

IV. RESEARCH AND DEVELOPMENT

Progress Since 1900

Although agricultural research in developed countries may reckon its origins mostly from the 19th century, research in the tropics and sub-tropics did not start before the 20th century, and was at first concerned exclusively with export crops - often for the textile and beverage commodities. Research in the food crops grown and consumed in the tropics made little progress until the end of World War II and the twilight of the colonial era.

In the case of potatoes, progress was slow even in the first half of the 20th century, but we must not forget the bright lights that shone on the origins and genetic improvement of cultivated potatoes from a group of plant breeders - first from the former Imperial College of Tropical Agriculture in Trinidad, from the 1930s, later followed up in Cambridge and Wageningen Universities and the Scottish Plant Breeding Society.

Government interest in potato research in the tropics was aroused first in Latin America, especially in Mexico, where a joint crop improvement programme was established in the 1940s, between the government and the Rockefeller Foundation, which was notably successful in developing late-blight resistant varieties. A number of bilateral programmes followed in tropical American and Asian countries, supported by Australia, Canada, Germany, the Netherlands, Switzerland, the United States and the United Kingdom.

Incidentally, interest in the genetic resources of Andean potatoes was stimulated at about this period among scientists at Cornell and Wageningen Universities when resistance to the Golden Nematode, Heterodera rostochiensis, was discovered in Solanum andigena; - this nematode being then a great menace to potato growing in Holland and the USA. Resistances were later identified also against 'Late Blight', 'Verticillium Wilt', 'Scab', 'Fusarium disease', 'Bacterial Wilt' and several viruses (A, X, Y, S, M and Leaf Roll).

Research interest was quickly followed by development projects. A particularly important national programme was established in India in 1944. A seed potato production station in the highlands near Simla initiated propagation and refrigerated storage of short-dormancy, virus-free seed tubers, which resulted in large scale potato production in the Punjab plains. National breeding programmes were started in Kenya in the 1960s and several South American countries later established programmes based on S. andigena crosses.

Co-ordination of research efforts on a global scale may be reckoned to start with the establishment of the International Potato Center (CIP) in Peru in 1971 by the Consultative Group on International Agricultural Research (CGIAR) under the sponsorship of the World Bank, the United Nations Development Program (UNDP) and FAO. Among CIP's successful "outreach" programmes, those carried out in co-operation with national programmes in Rwanda, Tunisia, Vietnam and Sri Lanka are particularly interesting⁽¹⁰⁾.

Rwanda's National Potato Programme⁽³⁾ (PNAP) was established in 1979 in co-operation with CIP and with financial aid from Belgian Technical Co-operation. The project concentrates on selection and multiplication of late-blight resistant varieties and on-farm production trials.

The Tunisian National Potato Programme was established in 1976 with financial assistance from the Canadian International Development Agency (CIDA) with CIP providing technical and administrative support. Production of locally multiplied seed tubers has proved very successful.

In Vietnam, in the 1970s the National Center for Scientific Research in Hanoi established a tissue culture laboratory in Dalat, where a rapid multiplication system for potatoes was developed based on tissue culture and stem cutting techniques. In 1979 germplasm obtained from CIP resulted in the selection of late-blight resistant varieties adapted to short-day conditions, which are now employed in a propagation industry based on the use of virus-free transplants for every third generation of seed tubers.

In Sri Lanka, the government ban on imports of consumer potatoes in 1967 led to a demand for cheaper home-produced seed tubers for local crop production. Seed from the late crop maturing in January had to be stored until the early crop planting in May. Advice from CIP led to widespread use by farmers of diffused-light storage structures, which by 1983 had largely solved the problem of importing seed tubers.

(See Annex B for further notes on specific countries.)

Research Priorities

In view of the leading role played by CIP in co-ordinating potato research in developing countries, the Center's research priorities may be taken as a general guide⁽¹⁰⁾. They may be summarised as follows:

- Collection and classification of tuber-bearing Solanum species;
- Breeding potatoes adapted to warm low tropics and sub-tropics and to cool mountainous environments;
- Control of important pests and diseases;
- Agronomy for warm areas;
- Post-harvest technology;
- Seed production for developing countries;
- Production economics.

Action on the first item must be concentrated, to some extent, in centres with the best access to the plant material and with suitable facilities, but research on the remaining items, with varying degrees of emphasis, is desirable in all developing potato growing countries - co-ordinated in regional research networks wherever suitable.

Without attempting to report on all subjects of modern research, it may be useful to give some indication of the main lines of investigation now taking shape in developing countries and their relationship to past scientific findings.

Varietal Selection

For obvious reasons, research usually starts with testing of introductions and selection of established varieties more or less adapted to local conditions. Mention has been made of the results obtained in an FAO-assisted project in Senegal, using known commercial varieties and available means of pest and disease control. Similar work has been attempted in other tropical countries but not always with the necessary rigour. In developing countries, it is essential to establish a 'base line' of the limitations of good available plant material and good cultural techniques, especially as regards yields, seasons and resistance to the major pests and diseases, in order to establish research priorities.

Breeding

The original cultivated varieties in the Andes were presumably selected from wild seedlings, according to desirable tuber characteristics. These seedlings must have been of great genetic diversity. Present estimates are of the presence of eight cultivated species and 200 wild species in Latin America. Moreover, although most cultivated species in the world are tetraploids, in Latin America there exist also cultivated and wild diploids, triploids, pentaploids and hexaploids⁽¹⁰⁾.

The original tubers imported into Europe at the end of the 16th century via Spain, Portugal and Britain were tetraploid cultivated potatoes of the Andigena group (8: J.G. Hawkes), i.e. Solanum tuberosum ssp. andigena.

However the quantity and range of varieties imported into Europe at the end of the 16th century was very limited. They are believed to have been all tetraploids of the Andigena group⁽⁸⁾ (J.G. Hawkes) and they must have been subject to severe losses due to lack of climatic adaptation. European varieties started, therefore, from a narrow genetic base.

The pioneer introductions were all short-day types but were evidently possessed of enough genetic variability to permit their adaptation

by a process of natural selection to produce a series of varieties which give high yields under the long days of the European summer.

Conscious selection of improved varieties accelerated in the 18th and 19th centuries and was perforce intensified after the epidemics of late blight in 1845-47⁽⁹⁾. A new direction of breeding and improvement was taken after the first Russian importations of cultivated and wild species from Latin America in 1925⁽⁹⁾.

Potato selection and improvement in the 19th century had in fact been conducted by farmers and a few interested scientists, but now and since the 1930s it has been concentrated in public agencies. It must be admitted, however, that despite prolonged efforts, progress has been limited.

Breeding involving the combination of desirable characters from very heterozygous cultivars presents many difficulties. Hundreds of thousands of selections have been made over the years, in fact, but only a few dozen have become established commercial varieties. It has proved difficult to supercede some of the outstanding strains which were bred thanks to various strokes of luck over the last 150 years. For example⁽⁹⁾ "Russett Burbank" was released in 1876 but still accounts for 32% of the potato area in USA and Canada. Again, 20-30% of the area cropped to potatoes in Western Europe and even 40% in the Netherlands is planted to "Bintje", which was released in 1910! The parents of "Early Rose", still a major crop in the USSR, arrived in New York in 1851!⁽⁹⁾

These old varieties hold their place partly because of particular consumer qualities ("Russett Burbank" is very good for baking and processing, and "Bintje" has the yellow flesh and texture preferred in Western Europe), but their predominance is also due to the conservatism of modern markets, once they find a recognisable potato that suits their requirements.

The traditional cultivars are, of course, high yielding and of good appearance, but they are far from the ideal in their agronomic and pest resistant qualities. They have given surprisingly good results,

however, in some tropical environments when the right techniques and seasons were selected - although it is to be expected that even better results in climatic adaptability and pest resistance could be obtained from varieties bred for tropical conditions.

Despite the limited achievements in breeding for tropical conditions in the past, there is now reason to expect considerable advances. In the first place, great progress over the last 30 years has been made in taxonomic and genetic studies of the numerous tuber-yielding species in tropical and sub-tropical America and a large collection of species is maintained for breeding purposes by CIP⁽¹⁰⁾. Following this scientific advance, techniques of breeding have been developed which overcome interspecific incompatibilities. [These systems include induced polyploidy, crossing with diploid species, repeated back-crossings and recurrent selections.] Moreover, progress in the field of genetic engineering will probably offer new possibilities for potato improvement before long.

Encouraged by such prospects, many national research institutions in developing countries are now engaged in breeding programmes in co-operation with CIP.

Original breeding using Andean resources seems to be concentrated in Latin America. In addition to the leading role of CIP's central station near Lima, Peru, the other Andean countries of Bolivia, Colombia and Ecuador, and the larger Latin American countries Argentina, Brazil and Mexico, are all active in breeding studies and the use of Solanum tuberosum x S. andigenum hybrids is expanding (Mendibura and Huarte in Acta Horticulturae 213).

It was reported in 1987 by CIP⁽¹⁰⁾ that seventy potato programmes in developing countries had received germplasm for evaluation and that 36 clones had been multiplied by 22 national programmes and released to farmers. Nearly 350 clones now in advanced selection and variety trials in developing countries have resistance or tolerance to frost, nematodes, viruses, late blight, bacterial wilt or heat.

Biotechnology

Great progress has been made during recent years in the field of bio-technology. It is too early to report on applications to potato improvement, but it is probable that in the future RFLP planning and such techniques as:

- Protoplast culture regeneration and fusion,
- Microspore and Anther culture,
- Somaclonal variation, and
- Somatic embryogenesis

will be used to produce improved varieties, including varieties with improved resistance to the most dangerous pests and diseases (see Ref. 8 Proceedings of a recent symposium).

Control of Important Pests and Diseases

The most satisfactory means of crop protection lies in the use of disease and pest-free planting material and whatever techniques are used, the future probably lies in the creation, breeding, propagation and use of disease and pest-resistant varieties. Resistance can often be found in Andean varieties, with benefit to the control of viruses X and Y, bacterial wilt, the potato tuber moth and nematodes and it is highly desirable that the need for frequent applications of fungicides and pesticides should be reduced by means of resistance and the use of integrated systems of crop protection. Tissue culture now also offers a valuable assistance to control by providing a method of propagating virus-free planting material.

The most widespread and damaging disease is late blight, which for many years has been controlled by fungicidal sprays. Progress is now being made with blight resistance and 36 resistant varieties have recently been included in national blight resistance trials.

Trials of resistance to bacterial wilt are also in course in Asian, African and Latin American stations.

A more recent account of the application of plant biotechnology can be found in the proceedings of an international symposium organised

jointly by FAO and the Technical Centre for Agricultural and Rural Co-operation (CTA): "Plant Biotechnologies for Developing Countries", FAO, 1990.

CIP research in the entomological and nematological fields has concentrated on control measures for the potato tuber moth and the root knot and Andean cyst nematodes. Work is also in progress on virus resistance in developing countries especially for potato leaf roll virus and potato viruses X and Y.

Propagation

As noted in Section III, the greatest obstacle to the establishment of potatoes as a profitable crop in developing countries is the high cost of imported seed tubers and the absence of reliable local supplies of high grade material. A necessary adjunct to all crop development is the establishment of propagating centres in the production regions.

In the first place, traditional multiplication can be undertaken wherever there are sites on which the population of insect disease vectors can be kept at an adequately low level. This usually means highland stations with a suitable cool but frost-free growing season. It also means specialist training for station managers and technicians (which can usually be arranged). Regular inspection by a pathologist is desirable.

Recent research, however, has produced alternative methods of propagation which may become important in developing countries. These may be summarised as follows.

Tissue Culture

A modified system of tissue culture was invented in a research centre in Dalat, Vietnam⁽⁹⁾. In vitro cuttings are multiplied and transplanted in non-sterile soil. When planted out in the field, these plantlets produce small tubers suitable for crop production.

In the 1980's, this system was commercialised by some small farmers and became a local industry. Meristem culture now makes it possible to eliminate virus infection from explants and this provides an excellent means of restoring infected clones.

Tuberlets

Another useful method is the system of leaf-bud cuttings, which allows the production of miniature tubers 4-6 weeks after planting the cuttings. These tuberlets may be planted out after breaking dormancy to produce a crop of normal tubers. Since about 1000 tuberlets can be produced on a 3m² sand bed, this system allows extra quick multiplication of new varieties⁽¹⁰⁾.

True Potato Seed (TPS)

The use of true potato seed in breeding is, of course, normal, but its use for propagation has aroused great interest in recent years.

As all potato varieties are heterozygous, the seedlings they produce are usually too variable for commercial use, but research over the last ten years has indicated that ways may be found to overcome this problem. Use of TPS would be very valuable in tropical zones where seed tubers are costly and where their quality rapidly deteriorates due to the high temperatures and insect transmitted diseases.

The two main production systems investigated are: (i) production of ware potatoes directly from TPS, (mostly after transplanting seedlings to the field from seed beds), and (ii) production of tubers from TPS for use as "seed tubers" for crop production.

However, for TPS to become an alternative for commercial potato production it would be necessary to produce sufficient amounts of botanical seed of acceptable quality, producing uniform seedlings of high vigour, resistant to "damping off", fungal diseases and transplanting shock, etc. It would also be necessary to determine whether production costs could compete with in vitro propagation methods.

Post-Harvest Technology and Storage

Processed potato products are becoming important in the Philippines, but are relatively unimportant in most other developing countries.* The priority for research attention is storage, both of seed tubers and ware.

Refrigerated storage of seed tubers has become essential in the Indo-Gangetic plains to provide for seasonal plantings (see Annex B). Storage of ware potatoes in large refrigerated stores may become important in large Asian cities, as it is now in the USA, but in developing production areas emphasis is placed on on-farm storage using inexpensive well-ventilated stores. Diffused natural light storage of seed tubers has proved valuable for small farmers in several countries, to avoid excessive sprouting and high storage losses.

Research and Development Strategies and Programmes

The expansion of potato production and consumption in developed countries has depended to a large extent on private initiative. A large share of the total agricultural research and development budgets has been borne by the private sector and private companies have developed varieties, propagated seed tubers and manufactured fertilizers and pesticides.

In developing countries, however, research and development depends to a great extent on official initiatives and public finance. As a rule even the provision of seed tubers has to be undertaken initially by the government, since the market may be too small to interest international seed companies. The responsibilities for developing a new crop in these circumstances should not be under-estimated, involving as they do agricultural research and extension, rural development, quarantine control and the cost of imports, not to mention the construction of roads and railways.

*But see Wiersema, Ref. 12.

Research Planning

Obviously, hopes concerning the possibilities of potato production will depend on the results of production trials. In developing countries, special caution is needed in the estimation of yield potentiality. Yields per square metre obtained in experimental plots are usually many times the yield obtained by small farmers. The best estimates of yield potential are obtained by controlled trials on good commercial farms in the various suitable production regions. Such trials will need to be repeated at various stages during the progress of research and at each stage they should be combined with cost analysis.

Along with these commercial type trials on private farms, an 'applied research' programme at agricultural research stations will be needed to cover varietal selection, crop protection, production and propagation techniques. The establishment of seed potato propagation centres, preferably including in vitro techniques will have to follow. Fortunately, the advice and assistance of CIP is now available and should be obtained right from the planning stage.

The question of breeding for tropical environments, although of prime importance, is a matter for specialised potato breeders. The importance of the Andean species for breeding depends on the fact that they originated in various regions between 10°N and 20°S, at different altitudes above 2000 metres, with maximum variability in the altiplano around Lake Titicaca. They are therefore adapted to short day-lengths between 12 and 13 hours.

Modern breeding for varieties adapted to tropical regions must take into account every difference of 300 m (1000 ft) in altitude and every degree of minimum and maximum night temperatures.

Development Strategies

Agricultural development programmes are only successful if the social and economic conditions are favourable. The first step in the development of a national potato programme would therefore be a careful study of both production and market potentialities. A preliminary

survey of production areas and yields, costs of production, transport and marketing, should lead to an estimation of the price at which potatoes could be delivered to consumers. A market survey should reveal something of the level and seasonality of demand, consumer preferences as to potato quality and the price of alternative foodstuffs.

If the results of the surveys are encouraging, a full-scale feasibility study could be undertaken to determine in greater detail the quantities and costs involved in a development programme on a suitable scale. This will have to include both national expenditure on the production, transport and marketing side and any necessary provisions for import and agricultural credit.

Production Units

Plans depending on the creation of large state farms have usually proved unsatisfactory and even large projects to be managed by private companies may fail if they are not the result of long experience in the country concerned. The growing of potatoes to be sold in the market along with fresh fruit and vegetables is usually a business for small or medium scale farmers with holdings of good land within easy road distance of the markets. "Small" farmers usually have difficulty in marketing their produce because they are at the mercy of wholesale merchants. The most satisfactory solution to this problem may be the formation of farmers' marketing societies who grade, store and sell their produce as a group, purchase their supplies wholesale and supply their own transport. This can avoid the difficulties connected with co-operative societies with paid managers and bureaucratic controls⁽⁷⁾.

Any project to supply local food markets needs to be developed progressively and with elasticity, because it will be impossible to make accurate long-term forecasts of demand.

Extension Services and Supplies

Experience in developing countries has shown that the transfer of research results to farmers through national extension services needs special attention.

A potato research station needs to generate information on varietal selection, production and protection techniques, storage, etc., and to provide a service for the identification of pests and diseases and advice on control methods. It also needs an outreach officer or department specialising in the collection of information and its efficient distribution. In this way adequate co-operation can be established with the national extension service(s) both for the organisation of on-farm trials and demonstration and for the reception of up-to-date information on problems of crop production and protection.

It must be added that one of the most successful means of contact with small farmers is through the provision of essential supplies. Farmers who come to an extension office for help in obtaining supplies of agro-chemicals and even more, farmers visiting a seed tuber supply centre, will usually be anxious to discuss their problems. Moreover, the most effective way of encouraging development for small farms is through farmers' associations. Technology transfer can thus be associated with and made effective through socio-economic support.

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POTATO PRODUCTION AND CONSUMPTION IN SELECTED COUNTRIES

	Area 1000 Ha	Yield Kg/ha	Production 1000 MT	P.C. Consumption Kg/annum
	1979-81	1989	1979-81	1989 1980 1990
WORLD	19019	18064	14175 15469	269771 279437
AFRICA	615	806	8514 8711	5234 7022 65.27 53.88
Algeria	79	F120	6878 9167	540 F1100 29.309 23.704
Egypt	66	F 80	17399 21875	1142 F1750 6.284 4.913
Kenya	63	F 65	6390 4615	392 F 300 21.113 16.829
Morocco	35	F 40	14617 13750	503 F 550 18.622 10.410
Rwanda	34	F 40	6735 4600	229 F 184 30.071 37.350
South Africa	57	F 75	13304 13333	747 F1000 NA NA
N. & C. AMERICA	712	736	26553 28547	18914 21002 55.0 NA
Canada	110	F110	23818 26384	2626 F2900 79 NA
Mexico	78	F 72	12677 13394	993 F 964 10 NA
U.S.A.	491	518	30387 32160	14923 16659 52 NA

Legend: F = FAO Estimate

ME = Market Economies

E.Eur = Eastern Europe

N. & C. America = North & Central America

CPE = Centrally Planned Economies

Source: FAO Bulletin of Statistics 1990, vol. III/1

	Area 1000 Ha	Yield Kg/ha	Production 1000 MT	P.C. Consumption Kg/annum
	1979-81	1989	1979-81	1989 1980 1990
SOUTH AMERICA	985	929	9850	12570 9703 11679 22.993 23.501
Argentina	115	F113	16222	24779 1836 2800 53.120 61.246
Bolivia	170	127	4678	4893 794 622 84.708 99.469
Brazil	185	156	10816	13485 2002 2104 12.430 11.697
Chile	87	63	10299	14084 894 882 10.175 9.877
Colombia	150	175	12871	15666 1931 2737 46.025 37.655
Ecuador	30	59	10831	6800 323 400 30.777 55.162
Peru	213	F200	7521	8814 1593 1763 68.052 86.381
Venezuela	17	F 16	11277	13313 216 217 12.733 10.043
ASIA	4041	4604	12003	13323 48487 61430 6.244 5.367
Bangladesh	98	F121	9564	10331 942 F1250 8.223 8.782
China	2336	F2603	10888	11546 25415 F30053 10.500 12.876
India	741	F918	12639	15795 9377 F4500 8.318 6.728
Iran	87	F105	14336	13333 1269 F1400 26.944 12.861
Israel	5	F 6	36537	40000 200 F 240 .NA .NA
Japan	125	F123	26465	30081 3299 F3700 .NA .NA
Dem. Korea	125	F158	12289	13226 1535 F2050 62.863 55.584
Rep. Korea	37	F 27	12003	15944 452 F 431 5.541 10.086
Nepal	51	82	5527	7817 279 641 15.887 17.745
Pakistan	40	F 61	10413	9640 412 F 587 3.775 2.882
Turkey	177	190	16681	20526 2957 3900 52.967 46.443
WESTERN EUROPE	2188	1843	22756	25673 49788 47322

	Area 1000 Ha	Yield Kg/ha	Production 1000 MT	P.C. Consumption Kg/annum
	1979-81	1989	1979-81	1989 1980 1990
DEVELOPED M.E.	3020	2723	24053 26852	72631 73125
DEVELOPING M.E.	3015	3441	10893 12779	32845 43973
ASIAN C.P.E.	2553	2804	10895 11619	27708 32578
E.EUR + USSR CPE	10432	9006	13080 1426	136587 129761
DEVELOPED ALL	13451	11819	15540 17166	209218 202866
DEVELOPING ALL	5568	6245	10876 12258	60533 76551 10.982 10.746

ANNEX B

TRENDS IN POTATO PRODUCTION IN FIVE DEVELOPING COUNTRIES

The following brief accounts of production in Ecuador, India, Kenya, Korea and the Philippines are extracted from the CIP reports on development in the respective countries (see refs. 2, 10, 4, 11 and 1, respectively) and from FAO Statistics (Annex A).

They are presented as illustrations of the general trends in development discussed in the main text.

* * * * *

(i) Potato Production in Ecuador⁽²⁾

Potatoes have been grown in Ecuador for thousands of years and are still a major staple food. The farmers retain about 17% of their production for subsistence, and practically all of the remainder is marketed for consumption within the country. Current consumption is estimated by FAO to have been between 30 and 55 kg/capita/annum in recent years.

The crop is produced at high altitudes - 2400 to 3800 m in the Sierra mountain chain running down the centre of the country from North to South. It is mostly grown in small farms of 1-5 ha in valley bottoms or in terraces on the mountainside. The climate is tropical, so there is little seasonal variation in temperature, but the diurnal variations are great - the limit for cultivation is at the altitudes where night frosts prevail.

The two main planting seasons are May and November, reflecting equatorial rainfall patterns. There has been considerable variation in annual production due to changes in rainfall and disease attack. Recent national production has been 331,300 MT in 1962 and 407,602 MT in 1987. FAO Statistics quote a production of 400,000 MT in 1989 with a productivity of 6.8 MT/ha. Although there has been an official potato seed programme for 15 years, it is apparently only effective within a small radius of the government seed production farms.

There has been some externally funded research, with selection of a few improved Ecuadorian varieties, but the native varieties used by the majority of small farmers have not been produced in the seed programme.

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(ii) Potato Production in India⁽¹⁰⁾

Although the potato first arrived in Bombay in 1600, it did not spread widely until the 19th century. The potato was promoted by the British as a summer crop in the hills of northern India, especially around Simla, and spread to the plains as a winter crop, during the 20th century. It remained an expensive food until it began to be grown on a large scale in the Indo-Gangetic Plain.

This development has been due primarily to a government supported seed production programme. Production of seed tubers of short-day varieties, suitable for winter production in the plains, was made possible by the investigations of the Central Potato Research Institute, established at Simla in 1944. Farmers in the plains could not previously keep their own potatoes for seed, because their crop was heavily infested with viruses. They therefore depended largely on seed imported from Europe. They also obtained a little seed from the northern hills, but were limited to one variety ('Phulwa') with a short dormancy, which could be harvested in September/October and planted almost immediately in the plains.

Research workers in the Simla station developed a new multiplication system for the plants - small plots are planted in early autumn and harvested in January before the build-up of aphid infestation in February. The harvested seed is then kept in cold storage until planting time the following October. This development simplifies breeding work in the plains and since the early 1960's the Central Potato Research Institute has released a series of highly productive and disease-resistant varieties. A rapid progress in potato production in India has now reached the level of 14.5 million tons in 1989 (see Annex I), and has been accompanied by the establishment of privately-owned refrigerated warehouses with a capacity of 4 million tons, used primarily for potatoes.

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(iii) Potato Production in Kenya⁽⁴⁾

Potatoes have been grown in Kenya for over 70 years. Until the early 1920's the crop was grown only by white settlers for their own community and a small export trade. In later years, African farmers started to grow potatoes in the Rift Valley at altitudes of 1400-2700m as a subsistence crop and to export some to India and southern Africa. During the Second World War, production increased for army supplies. After the war years, a special effort was made by the government to clean planting material from viruses and bacterial wilt. The production centre moved to Meru.

In 1967 (after independence) the government prepared a potato development project, which concentrated on selection and multiplication and after 1972 also conducted field trials. Exports to the Middle East and to East African countries continued. Quantities between 1965 and 1976 varied from 500 to 4000 tons p.a.

A survey by CIP in 1980 estimated the area of production as equivalent to 75,000-100,000 ha pure stand, with an annual production of 400,000-500,000 MT. FAO estimates for 1989 were 300,000 MT produced on 65,000 ha with a productivity of 4.6 MT/ha. At present, most potatoes are grown on family farms of 2 ha or less, as one of several subsistence crops.

Production is largely restricted to the highlands to the North and North-west of Nairobi, with two crops a year, corresponding to the equatorial rainfall pattern. The seasonal pattern of planting and harvesting results in a year-round supply of fresh potatoes.

It should be borne in mind that potatoes occupy a relatively unimportant place in Kenyan market agriculture as compared with plantation crops, livestock and cereals. It has, however, become an important staple food for subsistence farmers in the highlands.

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(iv) Potato Production in Korea⁽¹¹⁾

Potatoes have been grown as a summer crop in the mountainous areas of South Korea since the early 1800's. At present 2/3 of the crop is grown in the lowlands - mostly in the spring, before vegetables or rice, plus a smaller crop in the autumn, following the vegetables.

Yields remained low at 11 MT/ha because of poor seed quality, and production dropped by half in the late 1970's due to the collapse of the Seed Certification System whose stocks had become heavily infected with virus diseases.

A new seed potato programme was established by the government in 1979 using tissue-culture for producing virus-free basic seed, and has now resulted in an increase of productivity to 20 MT/ha. Most of the commercial seed is produced by private farmers who multiply the tubers from the official programme under the auspices of a Horticultural Co-operative Association.

The Korean potato program has been very successful in producing high quality seed tubers, but has not made much progress in other areas - breeding, post-harvest technology and on-farm research. As of 1988, the seed program supplies certified seed of only three varieties, which - given the country's diverse agro-ecological zones - is considered to offer inadequate choice. It is also reported that, notwithstanding the progress made, potato seed has remained expensive and ware prices to consumers have remained high. The Republic of Korea is a rice-eating country with limited resources of arable land, and according to FAO estimates, potato production since 1980 has declined from 452,000 MT to 431,000 MT in 1989. [Production in the Democratic People's Republic of Korea (North Korea) over this period, incidentally, is reported to have been 4-5 times the Republic of Korea's (South Korea) total production, and their pro capita consumption many times greater.]

CIP has supported the South Korean programme in many ways and their report⁽¹¹⁾ submits proposals for improvements in potato research and development which could greatly increase potato production and returns to the Korean economy.

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(v) Potato Production in the Philippines⁽¹⁾

[The following facts and figures are taken from the interesting CIP report in 1989 by Crissman⁽¹⁾.]

Total annual production

Production of potatoes in the Philippines was officially reported as 20,000 MT from 6,000 ha in 1970 and 48,500 MT from 7,500 ha in 1986.

There is apparently some doubt about national productivity rates, but official reports in 1977 indicated 12 MT/ha in the highlands and 6 MT/ha at low and medium elevations. Reports for 1986 gave 11.2 MT/ha as the national average; 11.5 MT/ha for Northern Luzon and 16.1 MT/ha for Northern Mindanao. Production is located primarily in the high and mid elevation areas, at 1500-2700 m, of the Ilocos region of Northern Luzon, with a secondary centre round Bukidnon in Northern Mindanao at elevations between 500 and 1500 m.

Low productivity in some areas could easily be accounted for by the reported shortages of disease-free tubers and the difficult climatic conditions. The Philippines have a high-rainfall-humid-tropical climate, typical of South-east Asia, with precipitations of up to 4 metres p.a.

The main highland potato season is between February and July, with warm wet weather and occasional typhoons. The second season, with cooler drier weather from September, is the most important for lower elevations. Late blight, tuber moth and bacterial blight are common in most areas.

Luzon potato growers are nearly all market gardeners with farms of 1/3 ha to 4 ha. They are reputed to be skilled intensive growers who produce potatoes and cabbages, plus some carrots, beans and green onions for the Manila market, reached by a new main road - a journey of 200 to 300 km.

Returns from potato growing are said to be good and the growers fairly prosperous as a result of high retail prices in Manila. Per capita potato consumption is low - under one kg p.a. in this rice-eating country - but there is a growing appreciation of potatoes in the richer classes, especially for "chips" (U.S. "French fries") and crisps (U.S. "chips").

Arable land is scarce in the Philippines and official hopes for increased production are pinned on higher productivity, the main obstacle to which is the poor supply of good seed tubers.

Certified seed tuber schemes

For this reason, efforts have been made by the Bureau of Plant Industry (BPI), in co-operation with the German Agency for Technical Assistance (GTZ), from 1977 to 1987, to develop a complete system of certified seed potato production. However, by 1989, it was estimated that the quantity of certified seed reaching farmers was only 32-68 MT/year. The demand from farmers for improved seed is very strong and several other organized seed schemes have been established, but it appears that they have met with many difficulties in organisation. By 1987 they only provided an estimated 10% of national seed requirements, the remainder comes from a "farmer-based system" which provides tubers of poor quality. As imported seed is too expensive for most farmers, production suffers.

Good seed can be grown in the highland areas of Luzon and, despite problems, considerable technical expertise has gone into potato development in recent years. The Philippines is, indeed, the lead country in the CIP regional research network for South-east Asia. It seems, however, that the working of the high altitude seed farm in Buguias and the organisation of seed production in Benguet region with contract growers ran into management difficulties. [These problems are discussed in detail in the Crissman report⁽¹⁾.]

Research and breeding

On the scientific and technical side, development efforts have been more successful.

The CIP Region VII Breeding Program (Los Baños) made progress in developing varieties with bacterial wilt resistance, heat tolerance for lowland varieties and with thrips resistance. Material is shared with the potato breeding program of the Institute of Plant Breeding (Baguio-Buguias); BPI has also run a varietal selection programme since 1977 which has resulted in several recommendations to the seed board; some varieties have found their way from demonstration plots in farmers' fields into commercial production.

It is noteworthy that McDonald's (of fast food fame) has taken an interest in the introduction of varieties suitable for processing.

Rapid multiplication techniques

In view of the difficulties suffered in seed tuber propagation, it is noteworthy that rapid multiplication techniques with a tissue culture laboratory and in vitro capability have been in operation since 1983. In vitro derived mother plants are the source for subsequent rapid multiplication by nodal cuttings, top-shoot cuttings and multiple stem cuttings and the production of pre-basic seed.

It seems that these modern techniques are well established and successful in the centres in Banguet in Luzon, and Bukidnon in Mindanao. This has not been achieved without trouble. It is reported that a serious virus infection occurred in the BPI greenhouse in Baguio in 1983 and an infection of bacterial wilt caused a major disruption at the Buguias seed farm in 1986. The contamination problems were overcome, but have revealed the need for strict sanitary control and the education of nursery staff in matters of plant hygiene.

A most important subsequent development has been the establishment of farm-based nurseries run by Baguio trained co-operators. One of the

successes has been the distribution of nematode-resistant varieties in a district infested with the very dangerous cyst nematode.

True potato seed

The use of true seed has not yet passed the experimental stage in the Philippines. CIP-BPI farm trials have shown promising results in Negros and a co-operative has established a screenhouse nursery in Mindanao.

The usual trouble with instability of varietal character has so far proved discouraging.

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